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Can exposure variation be promoted in the shoulder girdle muscles by modifying work pace and inserting pauses during simulated assembly work?

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ABSTRACT

This study investigated the acute effects of changing the work pace and implementing two pause types during an assembly task. Eighteen healthy women performed a simulated task in four different conditions: 1) slow or 2) fast work pace with 3) passive or 4) active pauses every two minutes. The root mean square (RMS) and exposure variation analysis (EVA) from the trapezius and serratus anterior muscles, as well as the rate of perceived exertion (RPE) from the neck-shoulder region, were observed. Decreased RMS and RPE as well as more variable muscle activity (EVA) were observed in the slow work pace compared with the fast one. The pause types had a limited effect, but active pauses resulted in increased RMS of the clavicular trapezius. The findings revealed the importance of work pace in the reduction of perceived exertion and promotion of variation in muscle activation during assembly tasks. However, the pause types had no important effect on the evaluated outcomes.

1. Introduction

Work-related musculoskeletal disorders (WMSDs) in the neck-shoulder region are very common among subjects performing monotonous and repetitive work (Côté et al., 2008; Palmer and Smedley, 2007). The lack of variation in the biomechanical exposure is a suggested risk factor for workers who have developed WMSDs (Madeleine et al., 2003a; Mathiassen et al., 2003). Quantifying the variation of biomechanical exposure during work is important to prevent and control such disorders. This study employs the exposure variation analysis (EVA) in order to determine whether variation in biomechanical exposure can be achieved through modifications of work pace and inclusion of active and passive pauses. EVA is a temporal data analysis, traditionally used to quantify variations in biomechanical exposure during a specific amount of time (Mathiassen and Winkel, 1991; Reynolds et al., 2014; Villumsen et al., 2017).

Previous studies have shown that changes in biomechanical exposure can be analyzed through different metrics revealing the effect of interventions such as changes in work pace or inclusions of pauses (Mathiassen, 2006; Samani et al., 2009a, 2009b). Work pace is considered to influence the error rate, discomfort, muscle activity level, motor control, and performance in occupational tasks (Bosch et al., 2011; Escorpizo and Moore, 2007; Gerard et al., 2002; Mathiassen and Winkel, 1996; Srinivasan et al., 2015a, 2015b). However, the effects of the work pace on biomechanical exposure are conflicting.

In a study performed by Bosch et al. (2011), no difference was found between work paces when the biomechanical exposure in terms of the cycle-to-cycle variability of neck-shoulder muscle activity was assessed. On the other hand, when considering the pattern of movement execution, Srinivasan et al. (2015a) found differences among work paces when considering both the cycle-to-cycle standard deviation of the area under the movement curve and sample entropy. Furthermore, differences among work paces have been found when evaluating biomechanical exposure by means of EVA. For example, Mathiassen and Winkel (1996) reported less variation in upper trapezius activation at a slow work pace

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compared with a fast work pace. This indicates that the application of robust methods to analyze the biomechanical exposure may reveal information that would be left unnoticed.

The inclusion of pauses at work has been reported as an effective way to reduce the development of WMSDs in the shoulder and lower back (Juul-Kristensen et al., 2004). Some studies have also evaluated the effectiveness of resting breaks during monotonous work (Balci and Aghazadeh, 2003; Galinsky et al., 2000; Mclean et al., 2001). So far, resting breaks and passive pauses have not been shown to induce changes in the pattern of electromyographic activity (EMG) among computer workers (Brewer et al., 2006). However, active pauses (short periods of muscle contractions) have been shown to increase the exerted force, promote the redistribution of the muscle load, and change the pattern of the motor unit recruitment during low-intensity activities (Falla and Farina, 2007; Westad et al., 2003). The concept of active recovery in sport science inspired the conception of active pauses in the occupational context (Ahmaidi et al., 1996; Weltman et al., 1977). Indeed, active pauses have been shown to have potential benefits in terms of increased muscle oxygenation (Crenshaw et al., 2006), but the results from studies evaluating EMG outcomes are conflicting (Januario et al., 2016). Therefore, this study intends to reveal whether active pauses can increase variation in biomechanical exposure (EMG of neck-shoulder muscles) assessed by EVA.

When evaluating the acute effects of work pace and pause types, Samani et al. (2010a, 2010b, 2009b, 2009c) found that active pauses can change EMG with potentially beneficial effects on biomechanical exposure. Further, some evidence of an interaction between pause type and work pace on EMG amplitude and EVA applied to the trapezius EMG has been demonstrated (Samani et al., 2009a). Active pauses are potentially beneficial when a task is performed at a slow pace (Samani et al., 2009a) even though other studies report no difference between pause types (Crenshaw et al., 2006; Larsen et al., 2009); especially when the task is performed at a fast pace (Sundelin, 1993).

The discrepancies among the above-mentioned studies show that very little is known about the interactive effects of work pace and pause type across different work tasks. In particular, high intensity work tasks, such as industrial assembly, may reveal significant effects of such interventions. Therefore, this laboratory study evaluated the acute effects of the combination of slow and fast work paces with passive and active pauses during a simulated assembly task in terms of the biomechanical exposure in the shoulder girdle muscles of healthy subjects. We hypothesized that a slow work pace would result in more variable EMG signals compared with a fast work pace and that active pauses would increase the EMG variation during both paces when compared with passive pauses. Further, we hypothesized a possible interaction between work pace and pause types such that the effects of active pauses would acutely promote higher EMG variation at a slow work pace when compared with passive pauses at a fast work pace (Samani et al., 2009a; Sundelin, 1993). Laboratory experiments like this are necessary proofs of concept before such interventions are implemented at work.

2. Methods

2.1. Subjects

A convenience sample of 18 right-handed healthy women (age: 24.7 ± 2.6 years; body mass index [BMI]: 22.9 ± 2.2 kg/m^2) participated in this study. The sample size was based on previous studies and the statistical power was calculated by means of a post-hoc power analysis (G*power, v 3.1, University of Düsseldorf, Germany) (Erdfelder et al., 1996; Faul et al., 2007). Based on the results obtained for the normalized RMS of the acromial fibers of upper trapezius, the effect size (f = 0.78) was calculated. Adopting a repeated measures analysis of variance (RM-ANOVA) with an interaction between work paces and pause types, and with a significance level of 5%, the statistical power was 99% for the performed test. We included only women because they are more susceptible to develop neck-shoulder WMSDs than men (Côté, 2012) and because sex affects the motor control (Svendsen and Madeleine, 2010).

The inclusion criteria were: BMI ≤25 kg/m^2 and no experience performing repetitive tasks. The exclusion criteria were: report of circulatory, rheumatic or inflammatory systemic diseases or the identification of musculoskeletal disorders, pain or soreness in the neck-shoulder region or upper limbs in a physical examination (Ohlsson et al., 1994). All of the subjects gave their written informed consent before participating in the study. The Ethics Committee on Human Research from the Federal University of São Carlos (protocol number: 42092115.5.0000.5504) approved this study, which was conducted in accordance with the Helsinki Declaration.

2.2. Experimental procedure

Each subject started performing a training session to become familiarized with the experimental setup. The subjects also answered a questionnaire addressing personal information, physical activity levels (Craig et al., 2003), and musculoskeletal complaints (Kuorinka et al., 1987). Anthropometrical characteristics were also recorded. The workstation was adapted according to the ergonomic workplace analysis protocol proposed by the Finnish Institute of Occupational Health (Ahonen et al., 1989). Reference voluntary contractions (RVC) were then performed for EMG normalization purposes. Fig. 1A shows a schematic draft of the experimental protocol with detailed information presented below. After the RVC, the subjects performed three maximal voluntary contractions (MVC) of shoulder shrugs at the frontal plane to establish the load to be used during the active pauses (30% MVC). A digital dynamometer (DDK, Kratos, São Paulo, SP, Brazil) fixed to the ground was used to measure the force level during shoulder shrugs. Subsequently, the subjects were instructed to perform 40 min of a simulated task (Fig. 1B) which was divided into four periods (Periods A, B, C and D in Fig. 1A). In each period, the subjects performed a different combination of work pace and pause type. The order of the combinations was randomized.

2.2.1. Simulated task

The task consisted of a simple repetitive task simulating industrial assembly work. It comprised reaching for a target, manipulating an object, and sorting pieces using the right arm. The subject was placed standing in front of a table with the height adjusted below the elbow level as recommended for work tasks demanding free movements of the hands without high visual demand or precise grip (Ahonen et al., 1989). A wooden board (53 × 62 × 2 cm) with six different shapes of holes was placed on the table. A color was attributed to both the hole and the wooden piece according to their shape. A box with the wooden pieces was placed on the table with its center at a distance of 20 cm from the right edge of the wooden board. The box contained the entire set of the necessary pieces to complete the board (i.e. 340 pieces) and an additional 20% of pieces to facilitate the sorting (Fig. 1B). The subjects selected each piece and fitted it into the board holes. The wooden pieces weighed approximately 2 g and had a size of approximately 2 cm^2. The subjects were instructed to grip the piece with the right hand, using the index and middle finger as well as the thumb.